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RIVER POLLUTION AND PURIFICATION

A Study of the Effect of Chicago Sewage Upon the Water Supply of St. Louis

By T. J. BURRILL

WITH THREE PLATES

The Chicago River discharges into Lake Michigan through one main channel made navigable for the largest lake vessels, and has two branches which run nearly north and south respectively through the city. This stream, which ordinarily has otherwise a comparatively small flow of water, receives the sewage of about 1,600,000 people—four-fifths of the inhabitants of the great city—beside an enormous amount of wastes from manufactories. The river has almost no fall. Originally the current was always sluggish and when by reason of the wind the level of the lake was temporarily raised there was none at all, or the direction of the flow was inland. Under these conditions the stream—we can hardly say water—consisted of a dark and seething mass of corruption, foul beyond the power of words to describe.

The sewage of about 400,000 people has been and still is sent directly into the lake through pipes bearing no relation to the river. The city water supply is from the lake and notwithstanding the intakes were pushed four miles from the shore the contaminations too often reach this distance. To prevent this and to purify the river has long been a problem of the utmost importance to the city and it has received the earnest attention of the authorities and the best studies of experts.

The Illinois and Michigan canal completed in 1848 connects with the south branch of the river at a point within the city called Bridgeport, and at this place a lock and pumping works were established to supply the canal when the water was otherwise too low for the boats. The canal discharged in part at Lockport, 29 miles away, and further at Joliet, 4 miles beyond, at both places into the Desplaines River. At the latter point the canal crosses the river by means of a dam and pool, so that the waters are well mixed, and continues onward to LaSalle, where it opens into the Illinois River 95 miles from Bridgeport.

At first the pumping at Bridgeport from the Chicago River was only to supply the needs of navigation but as early as 1865 the city arranged with the canal commissioners to utilize the pumps for cleansing the river. From time to time other means have been adopted for this purpose, but most reliance has been placed, especially of late, upon these pumps, by which the waters of the lake were caused to flow in a slow current, at least part of the time, through the river course into the canal and thus at length into the Illinois River. This operation, gradually increasing in proportions, continued from the date mentioned onward through the remaining years of the century, and at its close there was thus poured into the canal about 35,000 cubic feet per minute of the river water and sewage, of which the latter contributed an estimated amount of 26,000 cubic feet.[1] This sewage, including wastes from the stock yards, carried, according to the same authority, the equivalent of 150 tons of dry organic matter and ammoniacal salts daily into the canal. Still the river was not cleansed and something more effectual became imperative. The increase of pollution with little dilution made the effluent stream more and more noxious to the inhabitants along its course especially in its upper reaches and more and more contaminated the city water supply. There was therefore a double reason for some heroic action.

After wide examination of systems of sewage disposal in use, and with much expert consultation, a bill was introduced in the state legislature, which became in 1899 an Act creating the Chicago Sanitary District and authorizing a sanitary canal through which by gravity might pass 600,000 cubic feet per minute of water from Lake Michigan into the Desplaines and hence onward down the Illinois River. This canal begun in 1892 was completed sufficiently to turn in the water on January 17, 1900, after an expenditure of over $30,000,000. It connects with the south branch of the Chicago River and discharges into the Desplaines at Lockport over a controllable dam. It is 29 miles in length and runs somewhat parallel to the

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[1] Long, Sanitary Investigations, Springfield, Ill., 1900, p. 37.

Illinois and Michigan canal, which remains as before. The flow maintained during the first year (1900) varied from about 150 to 220 cubic feet per minute with some lower and some higher quantities. This is to be compared with 35,000 cubic feet previously pumped. The reversed flow of the river through the city was made in the interests of shipping not to exceed 3 miles an hour, but the effect was speedily to change the black, maladorous cesspool into a stream of blue water from the lake. The sanitary canal is an immense relief to Chicago. What is its effect upon the valley of the Illinois River and below?

To make this more intelligible some description of the water course onward is required. The Illinois River is formed by the junction of the Desplaines and Kankakee about 16 miles below Lockport (12 miles southwest of Joliet). The Desplaines varies above Lockport from nothing during dry seasons to more than 300,000 cubic feet per minute at flood times, while the more stable Kankakee ranges commonly from 30,000 to above 300,000. Further down stream the main tributaries are the Fox, about two-thirds the size of the Kankakee; the Vermilion, more like the Desplaines, sometimes practically dry but subject to floods; Spoon River, most of the year a small stream, usually not above 5,000 to 10,000 cubic feet flow; and the Sangamon, as large as the Kankakee. Besides these there are a large number of smaller tributaries.

At Kampsville, 30 miles above the mouth of the Illinois where it joins the Mississippi, the government maintains a dam and keeps a record of the water. At one time in September, 1899, there was a flow of only 10,000, but in June, 1902, there passed the station about 9,300,000 cubic feet per minute. These are extremes. Prior to the opening of the sanitary canal there was commonly a flow here from March to June inclusive of about 1,000,000 to 3,000,000, and from August to October, of about 250,000 to 500,000 cubic feet per minute, the latter not being more than the proposed flow of the sanitary canal. Since the latter was opened the stream throughout has been very noticeably greater than it was before during its lowest stages, but it commonly is a large river at all times. Its length from the junction of its head waters to Grafton at its mouth is 263 miles.

All the main tributary streams are strongly sewage-polluted and there is a very extensive wash from a great area of highly fertile and well-populated regions, though with the exception to be noted the amount of organic matter entering from any one point received from other sources is small compared with that from Chicago. The exception is in the case of Peoria and Pekin. Here, as is well known, exist the largest distilleries and glucose factories in the country and great numbers of cattle are kept and fed upon the slops. The direct wastes from the manufactories and all the offal from the cattle sheds go directly into the river. This added to the sewage of some 70,000 people makes the contamination of the stream at this point only short of that from Chicago. Sometimes masses of filth collect in the river to such an extent that in times of low water dynamite has been used to break up the stranded islands composed of it. We shall see below results of this pollution in the prodigious multiplication of the number of bacteria in the water.

As related above, the sanitary canal was opened in January, 1900. Anticipating this event the trustees of the Chicago drainage district, acting upon the advice and cooperation of Arthur R. Reynolds, M.D., Commissioner of Health of the City of Chicago, arranged in 1899 for an exhaustive chemical and bacteriological study of the stream from Bridgeport to St. Louis. In order that this work might have all possible weight and that the results might be abundantly conclusive, Commissioner Reynolds was given authority to secure under his own general direction prolonged series of independent examinations and analyses by several well-accredited experts. In the fulfilment of this task the Commissioner arranged for the work by the Municipal Laboratory of Chicago, by the laboratory of the University of Chicago, and by that of the University of Illinois. He endeavored also to secure the cooperation of Washington University or of the City Laboratory of St. Louis, but in this was not successful. The work as undertaken was put in charge of Dr. Adolph Gehrmann of the laboratory first named, of Professor E. O. Jordan of the second, of Professors A. W. Palmer and T. J. Burrill of the third. In the latter case the bacteriological examinations were conducted by the present writer and his results alone are herein given, except that other general conclusions are mentioned.

The work was commenced in May, 1899, and continued uninterruptedly until October, 1900. Further examinations, made during the latter part of the year 1901, did not significantly modify the earlier conclusions. Collections, usually one each week at each place, were made from 38 carefully located stations on the course of the stream and tributaries, including the canals above named, the Desplaines, Kankakee, Fox, Big Vermilion, Sangamon, Illinois, and Mississippi rivers and from Chicago and St. Louis tap waters. Comparative tests were also made of the Missouri River several miles above its mouth. During the period mentioned there were received by the writer and his assistants 2,800 samples, from which an aggregate of about 30,000 bacterial cultures were made. In all this two primary ends were sought: (1) To determine for each sample the number of bacteria in a cubic centimeter which could be made to develop colonies on a culture plate, and (2) to test the presence or absence in each sample of *Bacillus coli-communis.* In work of such magnitude, and upon waters generally so polluted, further refinements of analysis were impracticable or less important. The first was expected to indicate quantitative and the second to give the best obtainable knowledge of qualitative contamination, that is, whether or not such pathogenic species as *Bacillus typhosus* were present in the samples examined. In work of this kind it is impossible directly to identify the latter, but since the two species just named gain access to such water from intestinal evacuations the presence of one of them must give a comparative indication of that of the other.

There is no room for doubt as to the polluted character of the head waters of this stream. What becomes of the highly putrescible and often pathogenic germ-laden matter equal to 150 tons of dry matter daily from Chicago and as much more from other sources that is persistently poured into the water?

The question has been much discussed and opinions have been exceedingly diverse upon what has been called the self-purification of running water. Somewhat misquoting an expression in a report of a British commission, it has recently been asserted before the American Medical Association that "biologists have about come to the conclusion that no river is long enough to purify itself." In a recent book on sanitation it is argued that the apparent purification in a river course is principally due to the dilution by pure water and not to any destruction of the organic matter with which the stream is originally polluted. "The theory of self-purification is now abandoned, or rather accepted only after so much modification that it is practically new."[1]

Because of contentions of this kind and otherwise the authorities of St. Louis, Missouri, became alarmed lest the Chicago contaminations should reach the intake in the Mississippi River, from which the city receives its water supply. An injunction has therefore been sought from the United States Supreme Court against the use of the sanitary canal, and the discharge into the Illinois River of Chicago sewage. This suit is now in progress. Let us see what bearings the investigations as summarized below have upon the problem.

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[1] Sedgwick: Principles of Sanitary Science and the Public Health, p. 129.

It is not possible to give in detail the figures for all the results of the cultures upon which this account is based. Neither does it seem feasible within the limits of permissible space to describe methods of procedure. It should be said, however, that the greatest possible pains were taken to have the collections properly made and shipped. The samples, taken in sterilized glass-stoppered bottles, securely sealed and tagged, were packed in ice and commonly reached the laboratory within eight to twenty-four hours after taking from the stream. After collectors and expressmen became accustomed to handling the packages, undue delay very seldom occurred and only in rare cases was the packing ice completely melted when the samples were received. Analyses were not made, or the results were not included in the case of any samples not received in good order. The collecting stations, so far as this account goes, are named in the table, with the distance in each case from Chicago.

For the colony count standard plating agar was used at 1% acid above the phenolphthalein neutral point and the plates were counted after a uniform development period of 10 days at 20° C. For the identification of *Bacillus coli-communis* carbolized lactose-litmus broth with 1 cc. of water was first incubated at 38° C. for 48 hours, and cultures indicating the presence of the bacillus were further continued for indol tests, glucose-fermentation tests, and milk coagulation tests. No animals were inoculated.

NUMERICAL VARIATIONS IN DIFFERENT PARTS OF THE STREAM

A very casual inspection of the table will show the wide variations in the monthly average number of bacteria in a cubic centimeter of the waters examined—from a few hundred to several millions. At first sight there may not appear to be any law in these differences, but further study will show that the numbers are always very large at Joliet and that there is generally, and usually very decidedly, a decrease to Averyville (North Peoria), then there is a very great increase at Pekin, followed again by a gradual decrease to Grafton (mouth of the Illinois River). For the sake of brevity the collections above Joliet are not given, but both in the Illinois and Michigan and in the sanitary canals the numbers of bacteria found were always represented by at least six and very often by seven places of figures, the latter more commonly than the other for the first-named canal. The largest average number for any one month during the whole work was from samples taken at Lockport, from the Illinois and Michigan canal in July, 1899, and reached 5,323,750, and the smallest from the stream anywhere from Bridgeport to St. Louis was from samples taken from the Illinois River at Grafton in October, 1899, namely 743. These, let it be noted, are each the averages of at least eight culture plates from four samples—weekly collections, duplicate plates. The largest count from a single sample, during the whole course of the work, was made from the water at Lockport, April 17, 1900, and showed 11,200,000. The largest monthly average from samples taken at Averyville (North Peoria), 159 miles from Chicago, was 129,500 for February, 1900, while the smallest was for June of the same year, *viz.*, 1,637; but the preceding November there were practically the same number, 1,640. At Grafton, 318 miles from Chicago and 143 from Pekin, the largest average was 191,500 from the Illinois for February, 1900, and 227,750 from the Mississippi river (above mouth of Illinois) March, 1900. The smallest monthly average at this place from the Illinois was, as above stated, 743 for October, 1899, and from the Mississippi 915 for July, 1899.

A very similar showing, subject naturally to wider variations in numbers, can be made by comparing the results of cultures from single samples taken on the same day (or at most not more than 24 hours apart) from each of any two stations differently located in regard to the principal source of pollution. In this way we may compare the colony counts in cultures from Bridgeport and Averyville, 159 miles apart, not by selecting maximum at one and minimum at the other, but just as they occur through given months. Here they are for November, 1899, and April, 1900.

	Nov. 7	Nov. 15	Nov. 21	Nov. 27
Bridgeport	4,790,000	1,960,000	3,920,000	4,315,000
Averyville	550	1,100	1,200	2,800

	April 3	April 10	April 17	April 25
Bridgeport	5,300,000	3,725,000	11,200,000	3,925,000
Averyville	28,000	17,000	5,500	1,850

This is scarcely a fair showing for a general difference in the two places, but it does illustrate excellently the marvellous decrease in the number of bacteria that takes place in the running stream during this distance of 159 miles. We shall see further along that there is only one way by which this decrease can be explained.

As before mentioned, the river receives immense quantities of polluting matter at Peoria and Pekin, and the number of bacteria very soon correspondingly increase. Havana is only 25 miles below Pekin and 37 miles below the main sewers of Peoria. There are no tributary streams of importance between these places except Mackinaw River, which carries a small volume of water drained from a very rich agricultural region and subject to much pollution. It enters a little distance south of Pekin. There is tabulated here the results of all the examinations made in July, 1899, and in September, 1900, from Pekin and Havana.

	July 7	July 13	July 20	July 26
Pekin	300,000	1,190,000	640,000	820,000
Havana	13,300	1,420	5,880	3,200
	Sept. 6	Sept. 14	Sept. 20	Sept. 27
Pekin	1,320,000	600,000	47,500	2,280,000
Havana	35,500	4,150	144,000	19,000

These results show as clearly as figures can show anything that there is some potent influence at work in cleansing the water. If these numbers were specially selected from the very great variations in the results as obtained, they would mean little or nothing, but an inspection of the whole counts as put down in the laboratory records shows that the lessons which may be drawn from such figures as the above are abundantly supported and any one may construct other comparisons from the monthly averages herewith presented, all teaching the same thing. The differences as shown for Joliet, Morris, and Ottawa are commended to the reader especially interested. There is practically no change in the volume of the water between Morris and Ottawa, 24 miles, but the difference in bacterial content is remarkable.

While with reference to particular counts there are many unexplained variations, the work in general very clearly and decidedly shows that the numbers of bacteria at the polluted headwaters of the stream are always very great, that these numbers more or less constantly decrease to Averyville, then decidedly increase below

Peoria and again decrease to Grafton, at which point the numbers are normal to the rivers in the region of the country under consideration. There are no more bacteria in the Illinois at its mouth than there are in the rivers tributary to the Illinois, nor than there are in the Mississippi above the mouth of the Illinois, or the Missouri above its junction with the Mississippi. Upon this point compare the monthly averages in the table. Here are a few of them:

	June, 1899	Oct., 1899	March, 1900	Aug , 1900
The Kankakee, Wilmington	22,837	11,075	72,250	1,975
The Fox, Ottawa	11,027	5,475	84,166	2,962
The Sangamon, Chandlersville	7,125	3,683	105,875	4,450
The Mississippi, Grafton	5,017	2,406	227,750	3,291
The Missouri, West Alton		16,325	179,750	12,450
The Illinois, Grafton	4,155	743	159,500	2,708

This gradual diminution of the numbers of bacteria down the stream from the place of pollution was equally evident before and after the opening of the Sanitary Canal. Any difference which the figures of the table reveal in regard to the results of 1899 and 1900 may easily be from other causes than the opening of the canal, except that the increased dilution by lake water decidedly reduced the number of bacteria in a cubic centimeter in the upper part of the stream, *i. e.*, above Ottawa.

SEASONAL VARIATIONS

So much for the variations in the bacterial content of the waters in the different parts of the stream. An examination of the figures will show that there is another marked difference according to seasons of the year. This is specially true in places distant from the points of principal contamination. Note for instance the figures at Averyville and Grafton. For easy comparison we may place together the average results for February and August, 1900, from a number of stations on the Illinois River as follows:

	Ottawa	Henry	Averyville	Beardstown	Grafton
February	228,000	160,500	129,500	420,500	191,500
August	18,830	1,850	8,000	15,000	2,700

The sewage contaminations are undoubtedly as great in the summer as in the winter. Are there other and added sources of bacteria in cold weather, or do the organisms sooner die in warm water? It has often been argued that the increase is prominently due to the greater washing from the soil in times of floods and it cannot be otherwise than that enormous numbers of bacteria do thus find their way into the rivers with every cubic inch of fertile soil, but this does not explain our tables of figures, neither does it commonly sufficiently explain results obtained elsewhere by other bacteriological analysts. Our floods come in March or later in the spring and the soil washes most after it thaws out; the bacteria in waters like that of the Illinois are more numerous before the ground thaws out and before the great floods occur. The river is nearly always much higher in June and July than it is in December and January, but the numbers of bacteria are in the reverse order.

Causes of Purification

This leads to the question so often asked and so variously answered: to what cause or causes must the "self-purification" of streams be attributed? The various answers include dilution, sedimentation, insolation, the effects of the plankton, etc. It is impossible here to enter the discussion of the subject, but it may be said at once that in the opinion of the writer the bacteria themselves constitute the chief agency. They are preeminently the purifying agents. When conditions are favorable they multiply with astonishing rapidity, so that the progeny of one may become millions in 24 hours. In such situations as have been herein described they are fermentation-workers. The organic wastes sent into the waters are rich food for these little creatures. In myriad numbers they attack it from all quarters. The solids are converted, in good part, into gaseous forms and come bubbling up through the filth-laden water. The supply rapidly decreases, the water becomes clearer, the bacteria die either as a prey to other organisms or by starvation. This, in a word, is the story. The more favorable the conditions, temperature among other things, the more rapid the process. In cold weather the fermentation is slower, the fermentable matter is carried further down stream; the bacteria live, not so fast but longer, and in the lower portions of the stream, distant from the place of pollution, are found in cold weather in greater numbers.

Qualitative Tests

It has seemed impossible to present the results reported above in briefer space, but there is little room to show those of the tests for

Bacillus coli-communis. This organism was found in all samples of the water taken at Joliet and above in 1899 and at Joliet in about 75% of the samples collected in 1900. Onward in the course of the stream the percentage of positive tests, showing the bacillus present, varied closely with the colony counts. The species, or species-group, was to some extent found in the waters from every station upon the river and its tributaries. Whenever and wherever the count showed 100,000 or more bacteria to the cubic centimeter this species was commonly among them though it seemed to be evident that in the " survival of the fittest " others longer existed and sometimes greatly multiplied. At Averyville the positive tests were found to be about 30% of the whole number, the lowest anywhere in the stream; below Peoria about 90% and at Grafton about 45%. At the station last named the waters of the Illinois and the Mississippi rivers proved to be as near alike in this respect as in the total numbers of bacteria. The collections from the Missouri River at West Alton always showed higher colony counts and a very considerably greater percentage of positive tests for *Bacillus coli-communis* than did those at any time for the Illinois River at its mouth or from the Mississippi River above the junction of the Missouri. Such results were also true from the samples collected taken from the mixed waters of the two rivers last mentioned. Five samples were weekly taken at different points across the stream in line with the St. Louis pumping works, called Mitchell in the list of stations in the table, and the greater counts showed very plainly and constantly the worse contaminations of the Missouri, the percentage of all tests for the bacillus named rose to about 80 of positive determinations. This seems bad indeed for a municipal water supply, but in the light of the foregoing the charge cannot lie against the Chicago sanitary canal.

There is however a side-light here to which attention should be drawn. The records show that typhoid fever is commonly much more prevalent in recent years in Chicago than in St. Louis, though it may be taken to be certain that *Bacillus typhosus* has very often found its way into the stream along with so great numbers of *Bacillus coli-communis.* The lesson is that the former soon dies out and this is supported not only from theoretical considerations but from all actual tests wherever reported from similar conditions. There is not the slightest evidence known to the writer to show that the typhoid bacillus, even for one germ, ever passed in the stream from Chicago down to the mouth of the Illinois River. More probably the very many that have started in the current perished long before they reached the clearer water at Averyville.

On the other hand those which from the same source were poured directly into the lake water and sometimes as directly pumped back into the city mains, making the round perhaps in one or two days were vastly more likely to carry infection to many people. Chicago has suffered much and must continue to suffer in this respect until the sanitary system is completed. Four-fifths of the sewage has for many years gone into the river and with much greater dilution is now so disposed of. When the other fifth shall have been added the plague may cease and this without serious consequences elsewhere. It cannot be held, however, that the water from any open stream in a populated country is safe to drink. All cities must find other supplies or inaugurate purifying processes, now known to be feasible.

TABLE I—CHICAGO DRAINAGE WATER

Monthly Averages of the Number of Bacteria from Weekly Collections of Water taken at the Stations named in the first column during 1899 and 1900

Station	Miles from Chicago		Year	January	February	March	April	May	June
Joliet	33	Des Plaines River	1899						*1,445,000*
"		" "	1900	973,000	1,448,333	2,000,000	1,655,000	485,000	18,000
Wilmington		Kankakee "	1899						*22,837*
"		" "	1900	5,790	102,000	75,250	52,000	3,300	3,650
Morris	57	Illinois "	1899						*999,875*
"		" "	1900	2,737,500	1,731,250	1,593,750	392,500	46,200	246,125
Ottawa	81	" "	1899						*20,550*
"		" "	1900	256,250	228,000	116,750	68,500	15,125	14,237
"		Fox "	1899						*11,027*
"		" "	1900	12,275		84,166	49,250	5,800	2,412
La Salle	95	Illinois "	1899						*17,800*
"		" "	1900	192,400	278,750	367,666	96,125	13,050	12,275
"		Illinois and Michigan canal	1899						*170,050*
"		" " " "	1900	193,300	169,625	212,000	157,750	25,300	31,062
"		Big Vermillion River	1899						*7,062*
"		" " "	1900	13,750	45,912	103,125	33,000	22,270	8,550
Henry	123	Illinois "	1899						*64,350*
"		" "	1900	41,462	160,500	183,625	39,875	14,260	3,487
Averyville	159	" "	1899						*8,700*
"		" "	1900	27,570	129,500	93,375	13,087	15,920	1,637
Pekin	175	" "	1899						*1,500,000*
"		" "	1900	128,100	84,000	125,125	27,250	106,500	150,625
Havana	199	" "	1899						*6,816*
"		" "	1900	124,166	79,575	181,875	26,500	23,850	15,000
Chandlersville		Sangamon "	1899						*7,125*
"		" "	1900	10,620	101,433	105,875	13,625	11,850	29,562
Beardstown	231	Illinois "	1899						*4,400*
"		" "	1900	239,750	420,500	145,750	28,375	12,880	7,962
Kampsville	288	" "	1899						*5,316*
"		" "	1900	36,725	202,666	155,625	15,825	5,038	2,425

TABLE I—CHICAGO DRAINAGE WATER (*Continued*)

Monthly Averages of the Number of Bacteria from Weekly Collections of Water taken at the Stations named in the first column during 1899 and 1900

Station	Miles from Chicago		Year	January	February	March	April	May	June
Grafton	318	Illinois River	1899						*4,155*
"		" "	1900	46,600	191,500	159,500	14,550	6,850	6,875
"		Mississippi River	1899						*5,017*
"		" "	1900	13,750	69,625	227,750	66,750	10,580	3,650
Alton	333	Miss. R. 100 ft. from Ill. shore	1899						*2,457*
"		" " " " "	1900	20,470	86,500	119,750	18,125	17,620	13,125
"		" " " Mo. "	1899						*7,250*
"		" " " " "	1900	18,620	104,100	144,875	85,500	24,080	5,875
Mitchell	348	" 400 " Ill. "	1899						*19,706*
"		" " " " "	1900	35,087	113,100	98,166	17,500	21,800	14,875
"		" " " Mo. "	1899						*16,650*
"		" " " " "	1900	64,925	50,300	143,333	57,500	64,125	25,375
West Alton		Missouri River	1899						
"		" "	1900	84,960	40,066	179,750	77,000	66,200	63,375

Station	Miles from Chicago		Year	July	August	September	October	November	December
Joliet	33	Des Plaines River	1899	*2,848,666*	*3,220,000*	*217,000*	*1,145,000*	*1,023,000*	*1,026,250*
"		" "	1900	170,000	134,750	203,330			
Wilmington		Kankakee "	1899	*4,720*	*4,000*	*5,387*	*11,075*	*11,650*	*25,300*
"		" "	1900	950	1,975	4,950			
Morris	57	Illinois "	1899	*930,750*	*4,822,375*	*2,186,100*	*505,000*	*747,000*	*170,000*
"		" "	1900	42,375	76,600	624,750			
Ottawa	81	" "	1899	*9,298*	*7,512*	*40,100*	*33,050*	*18,070*	*261,766*
"		" "	1900	2,950	18,830	34,875			
"		Fox "	1899	*3,670*	*4,560*	*4,822*	*5,475*	*5,900*	*7,000*
"		" "	1900	3,266	2,962	9,375			
La Salle	95	Illinois "	1899	*6,370*	*11,875*	*9,700*	*27,112*	*11,910*	*101,400*
"		" "	1900	3,500	13,000	17,412			

TABLE I—CHICAGO DRAINAGE WATER (*Continued*)

Monthly Averages of the Number of Bacteria from Weekly Collections of Water taken at the Stations named in the first column during 1899 and 1900

Station	Miles from Chicago		Year	July	August	September	October	November	December
La Salle		Illinois and Michigan canal	1899	*157,766*	*241,000*	*166,375*	*131,250*	*164,400*	*223,000*
“		“ “ “ “	1900	38,375	17,200	73,775			
“		Big Vermillion River	1899	*4,510*	*1,480*	*3,102*	*3,987*	*14,050*	*12,787*
“		“ “ “	1900	5,475	7,000	2,200			
Henry	123	Illinois “	1899	*22,362*	*26,350*	*11,100*	*8,575*	*5,880*	*59,966*
“		“ “	1900	40,433	1,850	136,700			
Averyville	159	“ “	1899	*9,358*	*4,000*	*3,100*	*3,768*	*1,640*	*9,300*
“		“ “	1900	4,233	8,060	4,466			
Pekin	175	“ “	1899	*737,625*	*1,928,333*	*391,250*	*1,047,500*	*812,000*	*69,000*
“		“ “	1900	313,375	286,500	1,061,875			
Havana	199	“ “	1899	*5,950*	*5,725*	*6,137*	*12,433*	*159,040*	*301,333*
“		“ “	1900	24,125	21,362	50,662			
Chandlersville		Sangamon “	1899	*9,900*	*19,783*	*20,300*	*3,683*	*7,100*	*10,266*
“		“ “	1900	13,900	4,450	4,316			
Beardstown	231	Illinois “	1899	*1,352*	*10,287*	*3,039*	*5,000*	*26,070*	*114,100*
“		“ “	1900	4,275	15,090	5,550			
Kampsville	288	“ “	1899	*3,161*	*6,225*	*3,480*	*1,717*	*5,065*	*28,850*
“		“ “	1900	1,850	10,700	5,850			
Grafton	318	“ “	1899	*2,628*	*1,806*	*793*	*743*	*7,210*	*40,344*
“		“ “	1900	3,911	2,708	5,274			
“		Mississippi “	1899	*915*	*1,379*	*2,356*	*2,406*	*8,380*	*15,912*
“		“ “	1900	3,027	3,291	3,932			
Alton	333	Miss. R. 100 ft. from Ill. shore	1899	*1,242*	*3,319*	*3,612*	*2,775*	*9,600*	*23,750*
“		“ “ “ “ “	1900	3,266	3,180	6,687			
“		“ “ “ Mo. “	1899	*2,927*	*2,215*	*2,562*	*2,200*	*5,730*	*4,183*
“		“ “ “ “ “	1900	3,862	7,610	4,433			
Mitchell	348	“ 400 ft. “ Ill. “	1899	*5,737*	*11,700*	*5,325*	*3,075*	*5,037*	*9,816*
“		“ “ “ “ “	1900	26,191	6,110	4,357			
“		“ “ “ Mo. “	1899	*5,902*	*32,275*	*9,250*	*10,187*	*30,125*	*25,233*
“		“ “ “ “ “	1900	29,275	10,256	12,927			
West Alton		Missouri River	1899	*20,000*	*32,695*	*23,417*	*16,325*	*28,510*	*10,475*
“		“ “	1900		12,450	25,187			

EXPLANATION OF PLATES

Plate XV

Map showing the drainage stream from Chicago to St. Louis and location of stations at which collections of samples of water were taken for examination.

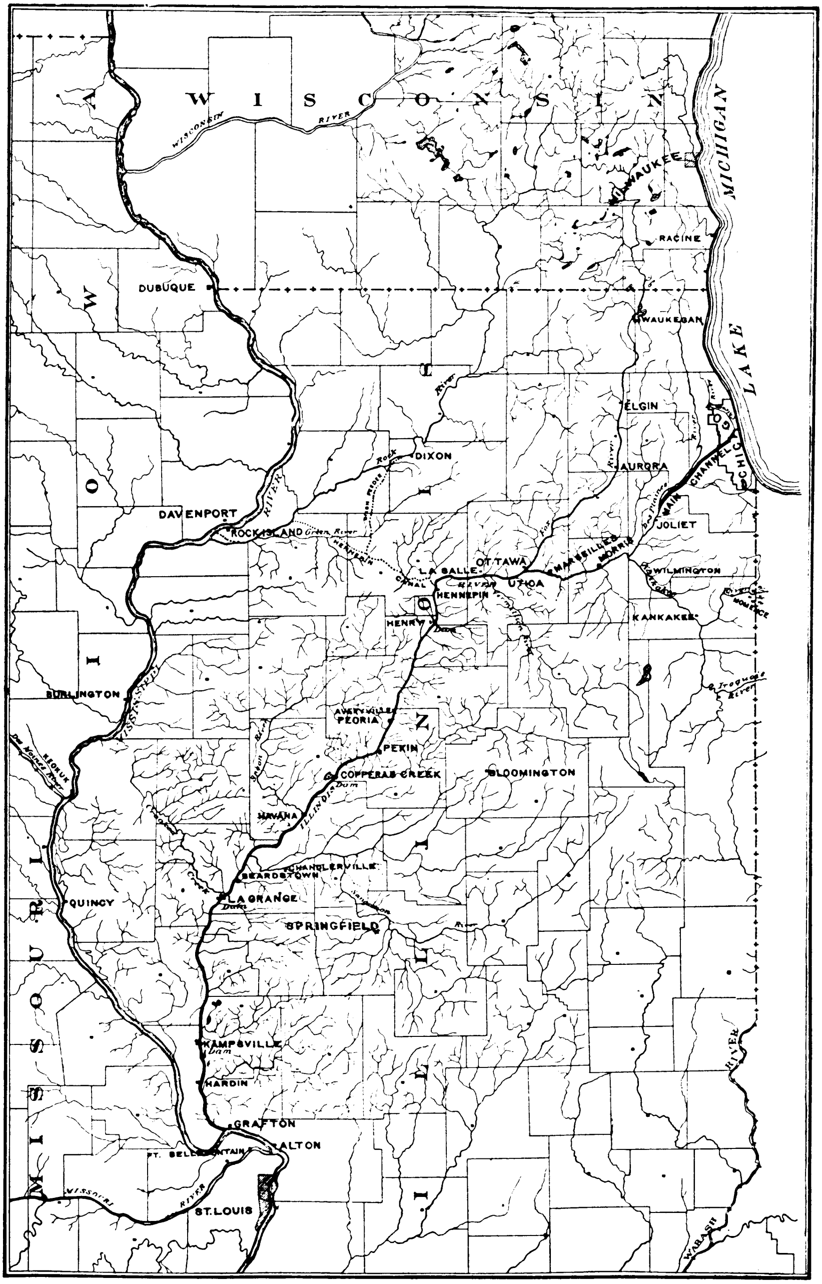
Plate XVI

A graphic representation of the average number of bacteria in the water at the stations named for the months of July, 1899 and 1900, before and after the sanitary canal was opened. Some of the lines run more than once across the plate because of their great length. Note how short they are during the lower course of the stream.

Plate XVII

Graphic representation of the identification of *Bacillus coli-communis* by percentages of positive results of total tests. The stream seems freest from this species at Averyville. The greater numbers at Mitchell appear to be due to the contamination of the waters of the Missouri River received above this point.

PLATE XV



WISCONSIN
WISCONSIN RIVER
MILWAUKEE
RACINE
MICHIGAN
LAKE
DUBUQUE
WAUKEGAN
ELGIN
AURORA
CHICAGO
MAIN CHANNEL
IOWA
DIXON
Rock River
DAVENPORT
RIVER
ROCK ISLAND
Green River
HENNEPIN CANAL
LA SALLE
OTTAWA
MARSEILLES
MORRIS
Des Plaines
JOLIET
Fox River
RIVER
UTICA
HENNEPIN
HENRY
Dam
Vermilion River
WILMINGTON
Kankakee
KANKAKEE
MOMENCE
Iroquois River
BURLINGTON
MISSISSIPPI
KEOKUK
Des Moines River
AVERYVILLE
PEORIA
PEKIN
COPPERAS CREEK
Dam
BLOOMINGTON
Spoon River
ILLINOIS
HAVANA
CHANDLERVILLE
BEARDSTOWN
Creek
LA GRANGE
Dam
Sangamon River
SPRINGFIELD
QUINCY
MISSOURI
KAMPSVILLE
Dam
HARDIN
GRAFTON
FT. BELLEFONTAINE
ALTON
MISSOURI RIVER
ST. LOUIS
WABASH RIVER

PLATE XVI

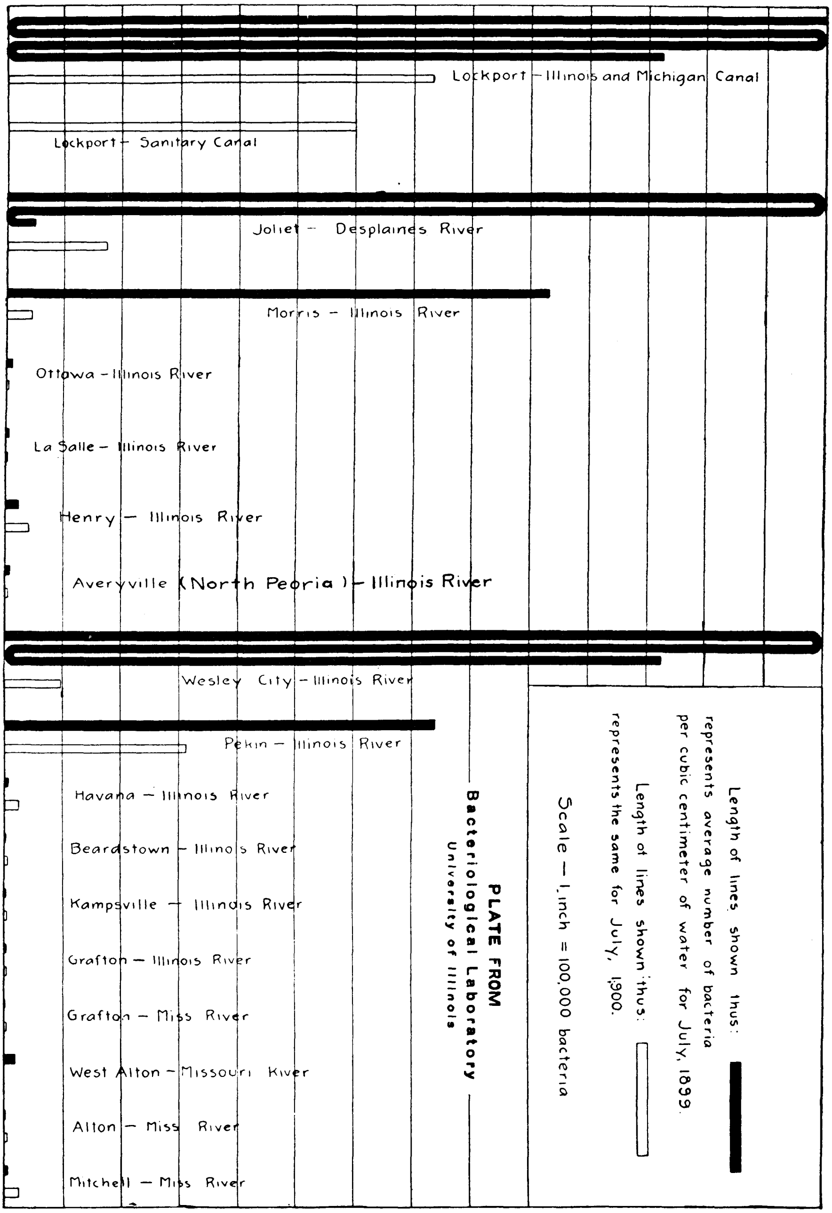
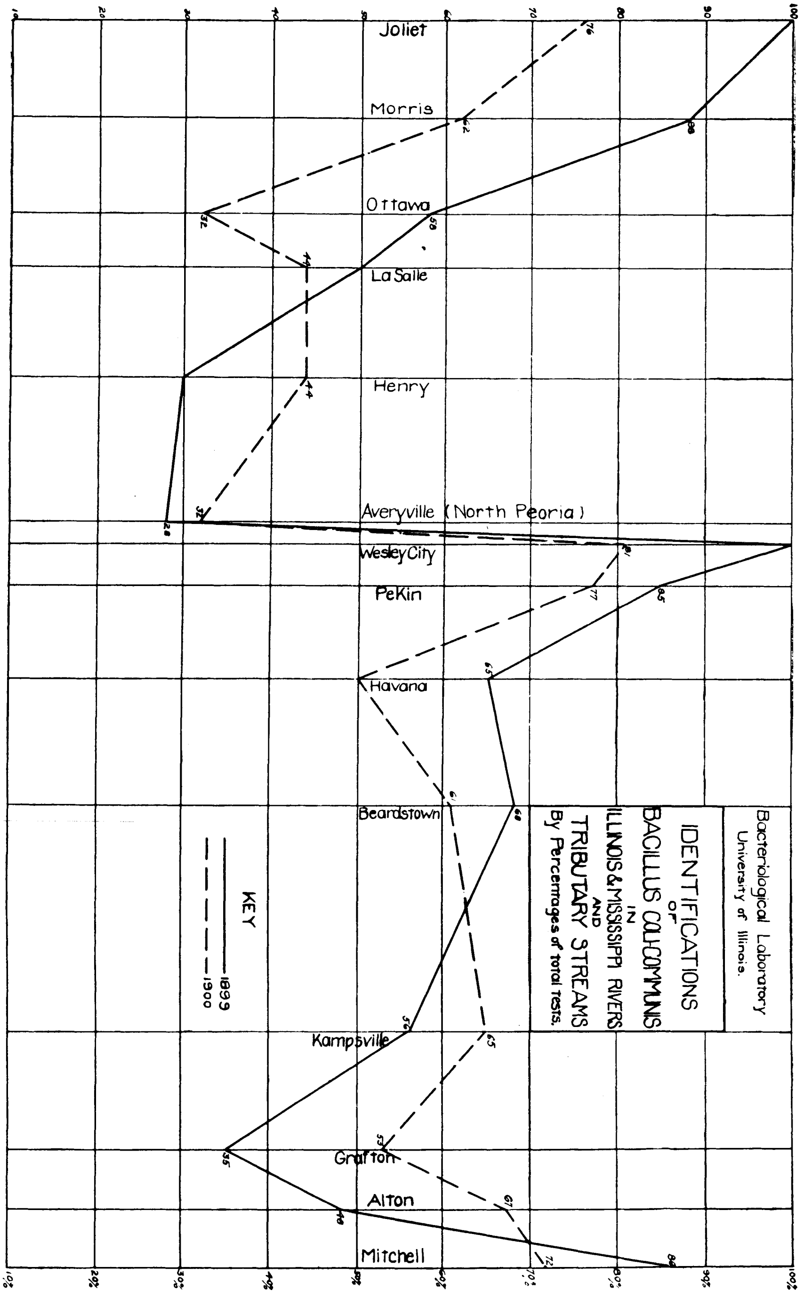

Lockport – Illinois and Michigan Canal
Lockport – Sanitary Canal
Joliet – Desplaines River
Morris – Illinois River
Ottawa – Illinois River
La Salle – Illinois River
Henry – Illinois River
Averyville (North Peoria) – Illinois River
Wesley City – Illinois River
Pekin – Illinois River
Havana – Illinois River
Beardstown – Illinois River
Kampsville – Illinois River
Grafton – Illinois River
Grafton – Miss River
West Alton – Missouri River
Alton – Miss River
Mitchell – Miss River
Length of lines shown thus: ▮ represents average number of bacteria per cubic centimeter of water for July, 1899.
Length of lines shown thus: ▯ represents the same for July, 1900.
Scale – 1 inch = 100,000 bacteria
PLATE FROM
Bacteriological Laboratory
University of Illinois

PLATE XVII


IDENTIFICATIONS OF BACILLUS COLI COMMUNIS IN ILLINOIS & MISSISSIPPI RIVERS AND TRIBUTARY STREAMS By Percentages of total tests.
Bacteriological Laboratory University of Illinois.
KEY
1899
1900
Joliet
Morris
Ottawa
La Salle
Henry
Averyville (North Peoria)
Wesley City
Pekin
Havana
Beardstown
Kampsville
Grafton
Alton
Mitchell
76
62
88
32
58
44
44
32
28
81
77
85
65
61
68
56
65
53
35
67
48
72
86
10
20
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70
80
90
100
10%
20%
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40%
50%
60%
70%
80%
90%
100%